May 1952 E-517, revised

United States Department of Agriculture
Agricultural Research Administration
Bureau of Entomology and Plant Quarantine

CONVERSION TABLES AND EQUIVALENTS FOR USE IN WORK RELATING TO INSECT CONTROL

By R. H. Nelson
Division of Stored Product Insect Investigations

Contents

In the literature on economic entomology the weights and measures used in expressing concentrations and dosages of insecticides may be in one or more of three systems--the United States, the imperial (British), and the metric. Since information on the relationships and equivalents in these systems is not always readily available to entomologists in the field, it has been assembled here for their benefit. The data on equivalents are taken principally from publications of the National Bureau of Standards (4, 5) and the International Critical Tables (6). A comparative discussion of United States and British units by Bearce (1) and a paper by Irwin (3) were sources of valuable information.

Tables of equivalents for use in diluting insecticides, methods of calculating concentrations on the basis of active ingredients, and certain other miscellaneous information useful to entomologists working with insecticides have also been included.

The measurement equivalents are carried out to sufficient decimal places to furnish accurate figures for precise laboratory work. They can be rounded out at the decimal place best suited for the equipment of the individual worker. The concentration equivalents have been carried out one to three places. In recommendations for practical use it is suggested that values be given as whole numbers or in steps of one-half wherever possible without gross error.

MASS

The basic units of the United States and British imperial avoirdupois systems differ in definition, but are equal for practical purposes. There are certain differences in terminology between the two systems that should be noted. A stone of the imperial system is 14 pounds. That system also uses 112 pounds as a hundred weight and 2,240 pounds as a ton. The hundredweight of the United States system is 100 pounds and 2,240 pounds is called a long ton. The latter unit is also the gross ton of maritime commerce, being originally based on an estimate of 12 pounds of container per 100 pounds of commodity.

The apothecaries and troy weight systems should not be used in entomological work, and fortunately their use elsewhere is dwindling. Except for the grain, homonymous units in these systems and the avoirdupois system are not equal.

The metric ton is sometimes referred to as a millier or a tonneau.

Units of Mass

U. S. and imperial avoirdupois		Metric	
1 grain (gr.)	1/7000 lb.	64.798918 milligrams (mg.)	64,698.918 micrograms (μg. or γ)
1 dram (dr.)	27.34375 gr.	1.7718454 grams (g. or gm.)	1,771.8454 mg.
1 ounce (oz.)	16 dr.	28.349527 g.	28,349.527 mg.
1 pound (lb.)	16 oz.	0.4535924277 kilogram (kg.)	453.5924277 g.
1 short ton	2000 lb.	0.90718486 metric ton	907.18486 kg.
1 long ton	2240 lb.	1.01604704 metric tons	1,016.04704 kg.
0.015432356 gr.	-	1 mg.	1000 μg.
0.5643833 dr.	15.432356 gr.	1 g.	1000 mg.
2.204622341 lb.	35.27396 oz.	1 kg.	1000 g.
1.1023112 short tons	0.9842064 long ton	1 metric ton	1000 kg.

CAPACITY - LIQUID MEASURE

The units of liquid measure have the same names in both the United States and the imperial systems. In no case, however, are they equal. The imperial gallon, quart, and pint are about 20 percent larger, whereas the imperial fluid dram and fluid ounce are about 4 percent smaller than the like-named United States units.

At 39.2° F. (4° C.), when it is at maximum density, a United States gallon of pure water weighs 8.345 pounds, an imperial gallon 10.022 pounds. At 62° F. (16.67° C.) these weights are 8.337 and 10 pounds. Twelve United States gallons (96 pints) of pure water weigh 100 pounds (very nearly) and 6 pints weigh 100 ounces (very nearly) at room temperature. The United States gallon is equal to 231 cubic inches and the imperial gallon to 277.418 cubic inches. There are 7.4805 United States gallons or 6.229 imperial gallons in 1 cubic foot. The United States gallon is the old English wine gallon no longer used in the British Empire.

Formerly in chemical and entomological literature the cubic centimeter (cc.) was commonly used as a misnomer for milliliter (ml.). Fortunately this is no longer such general practice. 1 milliliter = 1.000028 cubic centimeters; conversely, 1 cubic centimeter = 0.999972 milliliter. These units are related in the same sense as 231 cubic inches = 1 gallon. Occasionally the kiloliter is called a stere, but this word properly refers to the cubic meter.

Units of Capacity - Liquid Measure

United States		Imperial		Metric	
1 fluid dram (fl. dr.)	1/1024 gal.	1.0408 fl. dr.	-	3.69661 milliliters (ml.)	3,696.61 microliters (μl.)
1 fluid ounce (fl. oz.)	8 fl. dr.	1.0408 fl. oz.	8.3264 fl. oz.	29.5729 ml.	29,572.9 μl.
1 gill	4 fl. oz.	0.83268 gill	4.1634 fl. oz.	0.118292 liter (l.)	118.292 ml.
1 pint (pt.)	4 gills	.83268 pt.	3.33072 gills	.473167 l.	473.167 ml.
1 quart (qt.)	2 pt.	.83268 qt.	1.66536 pt.	.946333 l.	946.333 ml.
1 gallon (gal.)	4 qt.	.83268 gal.	3.33072 qt.	3.785332 l.	3,785.332 ml.
0.96075 fl. dr.	-	1 fl. dr.	1/1280 gal.	3.5515 ml.	3,551.5 μl.
.96075 fl. oz.	7.686 fl. dr.	1 fl. oz.	8 fl. dr.	28.412 ml.	28,412.0 μl.
1.20094 gills	4.80376 fl. oz.	1 gill	5 fl. oz.	0.14206 l.	142.06 ml.
1.20094 pt.	4.80376 gills	1 pt.	4 gills	.568245 l.	568.245 ml.
1.20094 qt.	2.40188 pt.	1 qt.	2 pt.	1.13649 l.	1,136.49 ml.
1.20094 gal.	4.80376 qt.	1 gal.	4 qt.	4.54596 l.	4,545.96 ml.
0.270518 fl. dr.	-	0.28157 fl. oz.	-	1 ml.	1000 μl.
1.05671 qt.	33.8147 fl. oz.	.8799 qt.	35.196 fl. oz.	1 l.	1000 ml.
264.178 gal.	1,056.71 qt.	219.97554 gal.	879.9 qt.	1 kiloliter (kl.)	1000 l.

Equivalents for Teaspoonful, Tablespoonful, and Cup

A measuring cup and measuring spoons, the latter obtainable in nests of several sizes, are useful for making dilutions under practical conditions where great accuracy is not required. The values given here are also useful in transposing the precise measurements of the laboratory into commonly understood units when recommending an insecticide to dooryard gardeners.

In the absence of suitable scales for weighing, the use of these volumetric units for measuring powdered insecticides is a common practice. Tables of equivalents for such use have been published (2). With the more recently developed wettable powders, however, weight-volume equivalents of wide application cannot be calculated because of differences in bulk volume and toxicant content of the numerous products. The expression "a pint is a pound" is exact for materials with a specific gravity of 0.96 and approximately true for water or for other materials with specific gravities near 1, but it is not true for powdered materials in general. It is suggested that those who wish to use volumetric measurements for powdered insecticidal material should determine the weight of such quantities as a tablespoonful and a pint, and record these figures on the packages at hand. Weight dilution directions can then be transposed to these volumetric units and the equivalents given here employed.

3 teaspoonfuls = 1 tablespoonful
2 tablespoonfuls = 1 fluid ounce
16 tablespoonfuls } = 1 cup
8 fluid ounces }

16 tablespoonfuls }
2 gills
1/2 pint
8 fluid ounces } = 1 cup
237 milliliters }

3 teaspoonfuls }
1/2 fluid ounce
4 fluid drams } = 1 tablespoonful
15 milliliters }

1 pint }
16 fluid ounces } = 2 cups
473 milliliters }

CAPACITY - DRY MEASURE

In the United States separate systems of capacity units are used for liquid and dry measure. In the dry-measure system, based on a modern standard of the Queen Anne bushel of colonial times, the pint and quart are about 16 percent larger than the units of the same name used in liquid measure. The pint of this system was originally designed to hold 1 pound of grain, presumably wheat. This relationship is not exact under present definitions. The United States bushel contains 2,150.42 cubic inches or 1.244 cubic feet.

The imperial system uses the same pint and quart in both dry and liquid measures. The imperial gallon may also be used, 8 gallons being 1 bushel. The pint and quart of the United States dry measure system

are about 3 percent smaller than the imperial units of the same name. The Winchester bushel, sometimes mentioned in publications from the British Empire, has the same capacity as the United States bushel. The imperial bushel contains 2,219 cubic inches or 1.2843 cubic feet.

In the metric system, capacity either liquid or dry, is measured by the liter and related units.

Units of Capacity - Dry Measure

United States		Imperial		Metric	
1 pint (pt.)	-	0.96895 pt.	-	0.550599 liter (l.)	550.599 milliliters (ml.)
1 quart (qt.)	2 pt.	.96895 qt.	1.937 pt.	1.101198 l.	1101.198 ml.
1 peck (pk.)	8 pt.	.96895 pk.	7.7516 qt.	0.880958 dekaliter (dkl.)	8.80958 l.
1 bushel (bu.)	4 pk.	.96895 bu.	3.8758 pk.	.352383 hectoliter (hl.)	3.52383 dkl.
1.03205 pt.	-	1 pt.	-	0.568245 l.	568.245 ml.
1.03205 qt.	2.0641 pt.	1 qt.	2 pt.	1.13649 l.	1136.49 ml.
1.03205 pk.	8.2564 qt.	1 pk.	8 qt.	0.9092 dkl.	9.092 l.
1.03205 bu.	4.1282 pk.	1 bu.	4 pk.	.36368 hl.	3.6368 dkl.
0.908102 qt.	1.8162 pt.	0.8799 qt.	1.7598 pt.	1 l.	1000 ml.
1.13513 pk.	9.08102 qt.	1.0999 pk.	8.799 qt.	1 dkl.	10 l.
2.8378 bu.	11.3513 pk.	2.74975 bu.	10.999 pk.	1 hl.	10 dkl.

LINEAR, SQUARE, AND CUBIC MEASURE

Except for small differences in standards, the units of linear measure in the imperial system are the same as those used in the United States and the same conversion values may be used. It follows that this is likewise true for the units of area (square measure) and the units of volume (cubic measure).

Units of linear measure occasionally encountered are the surveyor's (or Gunter's) link and chain. The link is equal to 7.92 inches, and 100 links, equal to 66 feet, make one chain. The engineer's chain is 100 feet long, being divided into 1-foot links. The nautical or geographical mile is equal to 1 minute of arc on a great circle of the earth and equals 6080.2 feet. A fathom used in nautical measurements is equal to 6 feet.

The acre, the basic unit of agricultural area measurements, contains 160 square rods or 10 square surveyor's chains. A square measuring 208.71 feet on each side is approximately 1 acre.

The relationship between the specific gravity of liquids or solids and cubic measure is of interest. Specific gravity x 1000 equals the weight in grams of 1 cubic decimeter or (very nearly) the weight in ounces of 1 cubic foot of the material. Since 1 cubic foot equals 7.4805 gallons (7.5 in round numbers), the weight-volume relationships of liquid or solid insecticidal materials can be calculated where their specific gravities are known.

Units of Length

United States and imperial		Metric	
1 inch (in.)	-	2.54 centimeters (cm.)	25.4 mm.
1 foot (ft.)	12 in.	3.048 decimeters (dm.)	30.48 cm.
1 yard (yd.)	3 ft.	0.9144 meter (m.)	9.144 dm.
1 rod (rd.)	16.5 ft.	.502921 dekameter (dkm.)	5.02921 m.
1 mile	5,280 ft.	1.6093472 kilometers (km.)	1,609.3472 m.
0.03937 in.	-	1 millimeter (mm.)	1000 microns (μ)
.3937 in.	-	1 cm.	10 mm.
.3280833 ft.	3.937 in.	1 dm.	10 cm.
1.0936111 yd.	39.37 in.	1 m.	10 dm.
1.988384 rd.	10.936111 yd.	1 dkm.	10 m.
0.6213699 mile	198.8384 rd.	1 km.	1000 m.

Units of Area

United States and imperial		Metric	
1 square inch (sq. in.)	-	6.451626 square centimeters ($cm.^2$)	645.1626 square millimeters ($mm.^2$)
1 square foot (sq. ft.)	144 sq. in.	9.290341 square decimeters ($dm.^2$)	929.0341 $cm.^2$
1 square yard (sq. yd.)	9 sq. ft.	0.8361307 square meter ($m.^2$)	83.61307 $dm.^2$
1 square rod (sq. rd.)	30.25 sq. yd.	.2529295 are	25.29295 $m.^2$
1 acre	43,560 sq. ft.	.404687 hectare (ha.)	40.4687 ares
0.15499969 sq. in.	-	1 $cm.^2$	100 $mm.^2$
.1076387 sq. ft.	15.499969 sq. in.	1 $dm.^2$	100 $cm.^2$
1.195985 sq. yd.	10.76387 sq. ft.	1 $m.^2$	100 $dm.^2$
3.95367 sq. rd.	119.5985 sq. yd.	1 are	100 $m.^2$
2.47104 acres	395.367 sq. rd.	1 ha.	100 ares

Units of Volume

United States and imperial		Metric	
1 cubic inch (cu. in.)	-	16.387162 cubic centimeters ($cm.^3$ or cc.)	16,387.162 cubic millimeters ($mm.^3$)
1 cubic foot (cu. ft.)	1,728 cu. in.	28.317016 cubic decimeters ($dm.^3$)	28,317.016 $cm.^3$
1 cubic yard (cu. yd.)	27 cu. ft.	0.7645594 cubic meter ($m.^3$)	764.5594 $dm.^3$
0.06102338 cu. in.	-	1 $cm.^3$	1000 $mm.^3$
.03531445 cu. ft.	61.02338 cu. in.	1 $dm.^3$	1000 $cm.^3$
1.3079428 cu. yd.	35.31445 cu. ft.	1 $m.^3$	1000 $dm.^3$

DILUTING INSECTICIDAL CHEMICALS

Equivalent Quantities for Various Quantities of Water

Powdered material.--The quantity of powdered insecticidal chemical recommended for use in sprays is usually stated in pounds per 50 or 100 gallons of water. Quantities in smaller quantities of water giving the same concentration as 1 to 5 pounds in 100 gallons are shown in table 1.

Note that the number of pounds per 100 gallons is the same as the number of ounces per 6 1/4 gallons. This relationship is also true for 50 and 3 1/8 gallons.

Liquid material.--Similar equivalents for use with liquid insecticidal materials, wetting agents, and the like are also shown in table 1. The relationship of pounds and ounces noted for powdered material holds here for pints and fluid ounces.

Concentration on the Basis of Percentage of Toxicant

In the preparation of sprays, dips, or dusts with certain insecticidal chemicals, the concentration is often based on the percentage by weight of the toxicant desired in the finished insecticide. The following equations may be found useful in determining the correct quantity of insecticidal chemical to use:

Suspensions.--To determine the quantity of insecticidal chemical necessary for a given percentage of toxicant in the diluted spray, multiply the number of gallons of spray to be made by 8.345 by the percent of toxicant desired, and divide by the percent of toxicant in the powdered material.

Example: 100 gallons of spray containing 0.06 percent of methoxychlor is to be prepared from a wettable powder containing 50 percent of the toxicant. The quantity of this powder to use is--

$$\frac{100 \times 8.345 \times 0.06}{50} = 1 \text{ pound}$$

To calculate the quantity of insecticidal chemical in grams, substitute 3,785.3 for 8.345.

The percentages of toxicant in 100 gallons of spray when 1 pound of wettable powder is used, calculated for powders of eight toxicant levels, are given in table 2. The quantities of these wettable powders necessary to give three concentration levels in 100 gallons of spray have also been calculated. These quantities may be rounded further, if necessary, in field work.

Table 1.--Quantities of insecticidal material giving the same concentration in various quantities of water

Water	Insecticidal material				
			Powder		
100 gal.	1 lb.	2 lb.	3 lb.	4 lb.	5 lb.
50 gal.	1/2 lb.	1 lb.	1 1/2 lb.	2 lb.	2 1/2 lb.
25 gal.	4 oz.	8 oz.	12 oz.	1 lb.	1 1/4 lb.
12 1/2 gal.	2 oz.	4 oz.	6 oz.	8 oz.	10 oz.
6 1/4 gal.	1 oz.	2 oz.	3 oz.	4 oz.	5 oz.
3 1/8 gal.	1/2 oz.	1 oz.	1 1/2 oz.	2 oz.	2 1/2 oz.
1 gal.	4.5 g.	9.1 g.	13.6 g.	18.1 g.	22.7 g.
1 qt.	1.134 g.	2.268 g.	3.402 g.	4.536 g.	5.670 g.
1 l.	1.198 g.	2.397 g.	3.595 g.	4.793 g.	5.991 g.
			Liquid		
100 gal.	1/2 pt.	1 pt.	1 qt.	2 qt.	1 gal.
50 gal.	1/4 pt.	1/2 pt.	1 pt.	1 qt.	2 qt.
25 gal.	2 fl. oz.	4 fl. oz.	8 fl. oz.	1 pt.	1 qt.
12 1/2 gal.	1 fl. oz.	2 fl. oz.	4 fl. oz.	8 fl. oz.	1 pt.
6 1/4 gal.	1/2 fl. oz.	1 fl. oz.	2 fl. oz.	4 fl. oz.	8 fl. oz.
3 1/8 gal.	1/4 fl. oz.	1/2 fl. oz.	1 fl. oz.	2 fl. oz.	4 fl. oz.
1 gal.	2.4 ml.	4.7 ml.	9.5 ml.	18.9 ml.	37.9 ml.
1 qt.	0.591 ml.	1.183 ml.	2.366 ml.	4.732 ml.	9.463 ml.
1 l.	0.625 ml.	1.250 ml.	2.500 ml.	5.000 ml.	10.000 ml.

Table 2.--Quantities of wettable powders of different strengths to give sprays or dips containing three concentrations of the toxicant

Percent of toxicant in wettable powder	Pounds to make 100 gallons			Percent of toxicant equivalent to 1 pound per 100 gallons
	0.25 percent	0.5 percent	1 percent	
20	10.4	20.9	41.7	0.024
30	7.0	13.9	27.8	.036
40	5.2	10.4	20.9	.048
50	4.2	8.3	16.7	.06
60	3.5	7.0	13.9	.072
70	3.0	6.0	11.9	.084
80	2.6	5.2	10.4	.096
90	2.3	4.6	9.3	.108

Emulsions and solutions. Diluting by weight.--To determine the quantity in gallons of an emulsion or solution concentrate to use in making up a spray containing a given percentage of toxicant by weight, multiply the number of gallons of spray to be made by the percentage of toxicant desired, and divide by the percent of toxicant in the concentrate times its specific gravity.

Example: 100 gallons of spray containing 2 percent of chlordane by weight is to be prepared from a 40-percent emulsion concentrate having a specific gravity of 1.02. The amount of the concentrate to use is--

$$\frac{100 \times 2}{40 \times 1.02} = 4.9 \text{ gallons}$$

Sufficient water is added to make 100 gallons of spray.

For field application, dosages of insecticides are often given in pounds of toxicant per acre. To determine the weight of toxicant, in pounds, in 1 gallon of emulsion concentrate, multiply 8.345 by the specific gravity of the concentrate by the percent of toxicant in the concentrate and divide by 100.

Example: An emulsion concentrate containing 45 percent of chlordane by weight and having a specific gravity of 1.07 is to be used. Each gallon of the concentrate contains--

$$\frac{8.345 \times 1.07 \times 45}{100} = 4 \text{ pounds of chlordane}$$

The quantity of water to be added depends on the method of application. If 1 pound of chlordane is required per acre, 1 quart of the above

concentrate should be used in the quantity of spray that the apparatus at hand will deliver per acre.

Specific gravity of a product is often unknown to the average user. These formulas can be used, leaving this factor out, and the results will be close enough for rough determinations.

Emulsions and solutions. Diluting by parts. --Emulsion and solution concentrates may be diluted by parts to obtain a desired percentage of toxicant in the finished spray or dip. It should be borne in mind, however, that 1 part of insecticidal chemical to so many parts of water is not the same as in so many parts of finished spray. The difference is of no great importance in the field use of dilute sprays, but it is of significance in the formulation of concentrated sprays and, of course, the distinction is desirable in the interest of precise terminology.

For diluting by parts divide the percent of toxicant in the concentrate by the percent desired in the finished insecticide. The result is the number of parts of the finished product that must contain 1 part of the concentrate. The liquid-capacity measuring unit to be used will depend on the total quantity of finished insecticide needed.

Example: A dip containing 0.2 percent of toxaphene is desired, and the concentrate contains 60 percent of the toxicant.

$$60 \div 0.2 = 300$$

The dilution is therefore 1 part of the concentrate in 300 parts of finished insecticide or 1 part of the concentrate to 299 parts of water.

To determine the percentage of toxicant in a spray or dip made up on the basis of parts, divide the percent of toxicant in the concentrate by the number of parts of the spray.

Example: A spray was made by diluting an extract of pyrethrum containing 2 percent of total pyrethrins at the rate of 1 part in 400 parts of spray.

$$2 \div 400 = 0.005 \text{ percent of pyrethrins in the spray}$$

Dusts. --To determine the weight of insecticidal material to use in preparing a dust containing a given percentage of toxicant, multiply the percentage of toxicant desired by the pounds of dust to be made and divide by the percentage of toxicant in the insecticidal material to be used.

Example: 100 pounds of dust containing 0.5 percent of rotenone is to be prepared from powdered root containing 4 percent of rotenone. The quantity of the root necessary is--

$$\frac{0.5 \times 100}{4} = 12.5 \text{ pounds}$$

Then add sufficient dilutent to make 100 pounds.

The percentage of toxicant in a dust may be determined when the quantity of insecticidal chemical used and its percentage of toxicant, as well as the total weight of the prepared dust, are known. Multiply the number of pounds of insecticidal chemical used by its percentage of toxicant, and divide by the number of pounds of dust prepared.

Example: 20 pounds of a powder containing 10 percent of DDT was used in making up 100 pounds of dust. The DDT content of the dust was--

$$\frac{20 \times 10}{100} = 2 \text{ percent}$$

Concentration Expressed in Parts per Million

Very dilute concentrations are often expressed in parts per million (p.p.m.) or as 1 part per stated number of millions, weight per weight or volume per volume. A list of equivalents is tabulated below.

Parts per million	1 Part per indicated millions	Parts per million	1 Part per indicated millions
0.001	1000	0.05	20.0
.002	500	.08	12.5
.004	250	.1	10.0
.005	200	.2	5.0
.008	125	.4	2.5
.01	100	.5	2.0
.02	50	.8	1.25
.04	25	1.0	1.0

In United States units 1 ounce in 7,500 gallons (more nearly 7,489.51) or 1 pound in 120,000 gallons (more nearly 119,832.22) is approximately 1 part per million by weight in water. One fluid ounce in 7,812.5 gallons is 1 part per million by volume. In metric units 1 part per million may be expressed as follows: By weight 1 milligram per kilogram, by volume 1 microliter per liter.

DOSAGE EQUIVALENTS AND RELATIONSHIPS

Dusts and Soil Insecticides

The quantities of dust or soil insecticide necessary for large-scale application, in pounds per acre, may be calculated from the quantities used in small-scale tests as follows: Multiply the number of grams or ounces per square foot by 43,560, or per square yard by 4,840, and divide by 453.59 if the dosage is in grams and by 16 if it is in ounces.

Example: A dust has been found effective in small-scale tests when used at the rate of 0.3 gram per square foot. The equivalent dosage per acre would be--

$$\frac{0.3 \times 43{,}560}{453.59} = 29 \text{ pounds}$$

To determine the number of square feet (or square yards) that 1 pound of a given material will cover when the dosage per square foot (or square yard) is known, divide 453.59 by this dosage if it is in grams, and 16 by this dosage if it is in ounces.

Example: In the dosage of 0.3 gram per square foot mentioned above, 1 pound of the material would cover--

$$\frac{453.59}{0.3} = 1{,}512 \text{ square feet}$$

To determine the quantity of material to be used for 1 square foot when the large-scale dosage is known, multiply the number of pounds per acre by 453.59 to obtain the number of grams, and by 16 to obtain the number of ounces, and divide the product by 43,560. For dosages per square yard divide by 4,840.

Examples: A dosage equivalent to 30 pounds per acre of a given dust is to be tried on a small scale. The dosage per square foot is--

$$\frac{30 \times 453.59}{43{,}560} = 0.31 \text{ gram} \quad \text{or} \quad \frac{30 \times 16}{43{,}560} = 0.011 \text{ ounce}$$

Some values that have been worked out for convenient reference are given in table 3.

Dosages in grams per square foot and pounds per acre are related approximately as follows: Grams per square foot x 100 = pounds per acre.

Table 3.--Large-scale dosages equivalent to various small-scale dosages

Dosage per square foot	Square feet that 1 pound will cover	Pounds per acre
Gram		
0.1	4,536	9.6
.10413	4,356	10.0
.15619	2,904	15.0
.25	1,814	24.0
.26032	1,742	25.0
Ounce		
0.005	3,200	13.61
.008	2,000	21.78
.01	1,600	27.22
.016	1,000	43.56
.025	640	68.06
.064	250	174.24
.16	100	435.6

It is frequently desirable to make such conversions on a weight-per-volume basis. A recent paper by Floyd Smith (7) gives a table for converting pounds per acre of soil 6 inches deep to equivalent dosages for various volumes of soil in pots and other containers. His conversion table is presented in table 4.

Table 4.--Milligrams equivalent to 1 pound per 6-inch acre in various soil units

Soil unit	Cubic centimeters of soil	Equivalent milligrams per unit
Standard pots:		
3-inch	180	0.132
4-inch	500	.368
5-inch	900	.662
6-inch	1,500	1.103
7-inch	2,400	1.765
8-inch	3,785	2.784
Short pot, 8-inch	2,900	2.133
Pan, 8-inch	1,400	1.030
Liter	1,000	.735
Gallon	3,785	2.784
Cubic foot	28,317	20.826
Bushel	35,238	25.916

Weight-Volume Relationships in Dosage Estimation

Surface application. --Dosage of residual insecticides for surface application are often given in milligrams of toxicant per square foot. If the percentage by weight of toxicant and the specific gravity of the spray are known, the approximate number of square feet that 1 gallon will cover at a stated dosage can be estimated by use of table 5. Select the factor opposite the dosage required and under the specific gravity of the spray at hand. Multiply this factor by the percentage of toxicant in the spray. Water suspensions of wettable powder may be regarded as having a specific gravity of 1.

Example: We wish to estimate the approximate number of square feet that 1 gallon of 5-percent DDT solution will cover at a dosage of 150 milligrams per square foot. The specific gravity of the oil solution is about 0.8. The factor 200 is read from table 5 and the calculation made as follows: $200 \times 5 = 1000$ square feet.

Field application. --Dosage in milligrams per square foot is approximately one-tenth the dosage in pounds per acre. The dosage figures in table 5 can therefore be read as pounds per acre by pointing off one place. To estimate the gallonage of spray required to produce a stated dosage in pounds of toxicant per acre, divide 45,300 by the selected factor in table 5 times the percent of toxicant in the spray.

Example: A dosage of 2.5 pounds of DDT per acre is to be applied by airplane. The oil solution to be used contains 10 percent of DDT and has a specific gravity of 0.9.

$$\frac{45{,}300}{1360 \times 10} = 3.33 \text{ gallons per acre}$$

Table 5 --Factors for use in estimating surface coverage of residual formulations and gallonage per acre

Dosage, (mg. per sq. ft.)	Specific gravity			
	0.8	0.9	1.0	1.1
10	3000	3400	3800	4200
25	1200	1360	1520	1680
50	600	680	760	840
75	400	453	506	560
100	300	340	380	420
150	200	227	253	280
200	150	170	190	210

Dosage Estimates for Row Crops

Equivalent dosages for certain acre rates and the areas or feet of row of three different spacings that 1 gallon of spray or 1 pound of dust will cover are given in table 6. Estimates of the requirements for areas less than an acre can be made from these figures.

Table 6. --Dosages for row crops equivalent to various dosages per acre

Rate per acre	1 Gallon or 1 pound will cover			
	Square feet	Feet of row with spacing between rows of		
		2 1/2 feet	3 feet	3 1/2 feet
		Sprays		
Gallons				
5	8,712	3,485	2,904	2,489
10	4,356	1,742	1,452	1,245
25	1,742	697	581	498
50	871	348	290	249
75	581	232	194	266
100	436	174	145	125
200	218	87	73	62
		Dusts		
Pounds				
5	8,712	3,485	2,904	2,489
10	4,356	1,742	1,452	1,245
15	2,904	1,162	968	830
20	2,178	871	726	622
25	1,742	697	581	498
50	871	348	290	249

FUMIGATION

Dosages of fumigants are commonly given in ounces or pounds per 1000 cubic feet. Metric equivalents may be calculated on the basis of the following relationship:

1 pound per 1000 cubic feet = 16.01894 milligrams per cubic decimeter

or

$$\frac{\text{Milligrams per cubic decimeter}}{1.00118} = \text{ounces per 1000 cubic feet}$$

Thus milligrams per cubic decimeter is approximately equal to ounces per 1000 cubic feet.

This relationship is of value in transposing laboratory dosages to conventional units for large-scale work and in determining the concentration of a fumigant, within a fumigation chamber, after proper chemical analysis of aspirated quantitative samples.

Other conversion values for gas concentrations that may be of value in fumigation studies are as follows:

1 cubic millimeter per cubic decimeter (liter) = 1 part per million by volume

1 percent by volume = 10,000 parts per million

Low concentrations of fumigants or vapors in the air, where the concentration in milligrams per cubic decimeter (liter) is determined, sometimes are expressed directly as parts per million--i.e., parts by weight to a million parts by volume. Unless it is clearly explained, such use of the expression "parts per million" is best avoided, that statement being reserved for ratios of weight to weight or of volume to volume.

The conversion of any weight-per-unit-volume ratio to a volume-per-unit-volume ratio, such as parts of vaporized fumigant per million parts of air, involves an understanding of the gram-molecular volume relationship. This may be stated as follows: The volume of a gram-molecule of a gas at 0°C. and 760 mm. of mercury is equal to 22.4 liters. At 25°C. and 760 mm. of mercury the volume is 24.45 liters or 24,450 milliliters. The latter figures approximate the conditions encountered in practical fumigation work. Conversion formulas based on these figures are as follows:

$$\frac{24{,}450 \times \text{milligrams per cubic decimeter}}{\text{molecular weight}} = \text{parts per million}$$

$$\frac{\text{Parts per million} \times \text{molecular weight}}{24{,}450} = \text{milligrams per cubic decimeter}$$

Example: A concentration of lindane vapor of 0.0006 milligram per cubic decimeter has caused high mortality of house flies. The molecular weight of this material is 290.85. The concentration may be expressed in parts per million by volume as follows:

$$\frac{24450 \times 0.0006}{290.85} = 0.05 \text{ p.p.m., which is equivalent to 1 part in 20 million}$$

Certain physical constants for a group of common fumigants are presented in table 7. The figures for milliliters per pound and per gallon have been rounded. Precise figures may be obtained by use of the specific gravity.

Table 7. --Physical constants for several common fumigants

Fumigant	Boiling point °C.	Molecular weight	Specific gravity at 20°/4° C.	Milliliters per pound	Pounds per gallon
Acrylonitrile	78	53.06	0.797	569	6.7
Carbon disulfide	46.3	76.13	1.263	359	10.5
Carbon tetrachloride	76.8	153.84	1.595	284	13.3
Chloropicrin	112	164.39	1.651	275	13.8
Dichloroethyl ether	178	143.02	1.222	371	10.2
Ethylene dibromide	131.6	187.88	2.180	208	18.2
Ethylene dichloride	83.7	98.97	1.257	361	10.5
Ethylene oxide	10.7	44.05	0.887(10°/4°)	511	7.4
Hydrocyanic acid	26	27.03	0.688	659	5.7
Methyl bromide	4.6	94.95	1.732(0°/4°)	262	14.4
Trichloroethylene	87	131.40	1.477	307	12.3

MISCELLANEOUS

Capacity of Sprayer Tank

The capacity, in gallons, of the tanks on sprayers may be calculated as follows:

Cylindrical tanks: Multiply length by square of the diameter, in inches, by 0.0034.

Rectangular tank: Multiply length by width by depth, in inches, by 0.004329.

Tanks with elliptical cross section: Multiply length by short diameter by long diameter, in inches, by 0.0034.

Diluting Miscible Liquids by Volume

Commercial grain alcohol of known percentage concentration can be diluted as follows: Into a 100-ml. graduate pour as many milliliters of the stronger solution as the percentage required in the weaker. Then add water until the mixture reaches the milliliter mark equivalent to the percentage of the stronger solution.

Example: To make 70-percent from 95-percent alcohol, pour into the graduate 70 ml. of the 95-percent solution and fill to the 95-ml. mark with water. The result is 95 ml. of a 70-percent solution.

The same procedure can be used for any other liquid, such as acetone, that is miscible with water, and in fact for any pair of miscible liquids.

Temperature Conversion

The two most commonly used thermometric systems are Centigrade (C.) and Fahrenheit (F.). Equivalents for the two scales may be calculated as follows:

$$^{o}C. = (^{o}F. - 32) \times 0.5556$$
$$^{o}F. = (^{o}C. \times 1.8) + 32$$

A number of equivalents for the two scales are presented below:

°F.	°C.	°F.	°C.	°F.	°C.
0	-17.78	80	26.67	158	70
10	-12.22	86	30	160	71.11
14	-10	90	32.22	170	76.67
20	- 6.67	100	37.78	176	80
30	- 1.11	104	40	180	82.22
32	0	110	43.33	190	87.78
40	4.44	120	48.89	194	90
50	10	122	50	200	93.33
60	15.56	130	54.44	210	98.89
68	20	140	60	212	100
70	21.11	150	65.56		

LITERATURE CITED

(1) Bearce, Henry W.
1936. United States and British units of weights and measures. Sci. Monthly 43: 566-568.

(2) Howard, N. F., Weigel, C. A., Smith, C. M., and Steiner, L. F.
1945. Insecticides and equipment for controlling insects on fruits and vegetables. Rev. U.S. Dept. Agr. Misc. Pub. 526, 56 pp.

(3) Irwin, K. G.
1951. Fathoms and feet, acres and tons: An appraisal. Sci. Monthly 72(1): 9-17.

(4) National Bureau of Standards
1936. Units of weight and measure (United States customary and metric). Definitions and tables of equivalents. [U.S.] National Bur. Standards, Misc. Pub. M 121, 68 pp.

(5) National Bureau of Standards
1920. Household weights and measures. U. S. Bur. Standards, Misc. Pub. 39, 2 pp.

(6) National Research Council
1926. International critical tables of numerical data, physics, chemistry and technology. v. 1, pp. 1-15. New York.

(7) Smith, Floyd F.
1952. Conversion of per-acre dosages of soil insecticide to equivalents for small units. Jour. Econ. Ent. 45: 339-340.

§§§